Vol. XVII *November, 1909.* *No. 6*

BIOLOGICAL BULLETIN

NEW AND LITTLE KNOWN HYDROIDS OF WOODS HOLE.[1]

CHAS W. HARGITT.

During the summer of 1907, while engaged upon certain problems associated with the work of the biological survey carried on at the Fisheries Laboratory, I described several hydroids, some new, others more or less rare, in a paper published in the BIOLOGICAL BULLETIN, January, 1908. During the following summer I was fortunate in finding a few others which, like the former, were in part new and in part hitherto unknown within the locality, and in one case at least, wholly new to American fauna. In the following account will be found such descriptions as seem called for in order to bring them definitely to knowledge as integral factors of the hydrozoan fauna of the region concerned.

CLADOCORYNE FLOCCOSA var. SARGASSENSIS.

In a mass of *Sargassum* which was picked up during the summer of 1907 in Vineyard Sound, bearing a rich hydroid fauna, I found a very minute hydroid which at first greatly puzzled me. It was intricately associated with other species, particularly with *Aglaophenia minuta*, and at first seemed to be a sort of nematophoric accessory of this hydroid, the small round heads of young specimens bristling with nematocysts having but little resemblance to an independent hydroid. But a more extended examination brought to light other and larger specimens, and soon it was found that the thing under examination was beyond doubt a very minute and apparently unknown species of hydroid. A series of developmental stages were found giving all conditions, from minute buds just arising from the stolon-

[1] Contributions from the Zoölogical Laboratory, Syracuse University.

iferous base to others with mere buds of tentacles, with still others having growing tentacles from the base of a definite hydranth on to the fully developed hydroid with full complement of tentacles, etc. Fig. 1 shows the hydroid enlarged ten diameters, while Fig. 2 shows the hydranth greatly enlarged to show the peculiar branching and knobbed tentacles. With this much clear it was not difficult to trace its generic affinities under *Cladocoryne*, Rotch.[1] But it was doubtful as to its specific relations. Rotch had described a species, *C. floccosa*, found at Herm, near Guernsey, having a habitat on stones, and being 6–12 mm. in height. Perrier has also described a species, *C. simplex*, found on *Sargassum*,[2] but I have not had access to Perrier's book, and so am unable to form any definite notion of that species.

FIG. 1.

The present species is very minute, being only 2–4 mm. in height and differing more or less as to other features. I have suggested for it a varietal distinction, proposing the name *sargassensis*, as indicative of its habitat. The following characters are diagnostic:

Trophosome. — Stems mostly simple, occasionally branching slightly, rising from a reticulate hydrorhiza. Hydranths relatively large, spindle-shaped, with elongated hypostome similar to that of *Pennaria*. Tentacles about twelve, variously branched and definitely knobbed, and disposed in some three verticels over the body of the hydranth. These tentacles are peculiar and thoroughly distinctive, both in structure and development. A second series of oral tenacles, about six or seven in number, are simple, with knobbed ends, and surround the mouth. All are richly packed with nematocysts.

The perisarc, both of stem and hydrorhiza, is rather dense and irregularly annulated.

Gonosome. — This is wholly unknown, in the present specimens at any rate.

Habitat and Distribution. — The present is the only time I have seen the species. As stated before it has its habitat on

[1] *Ann. Mag. Nat. Hist.*, March, 1871, Vol. VII., p. 227; Allman, "Gym. Hydroids," p. 38.

[2] Cf. Billard, "Exp. Talisman," p. 161.

floating *Sargassum*. I have hunted carefully over later collections of gulf weed but without finding trace of it.

CALYPTOSPADIX CERULEA Clarke.

On August 7, 1908, I found growing on the sides of the steamer Fish Hawk, at Woods Hole, several fine colonies of this hydroid, originally described by Clarke,[1] and so far as I am aware has

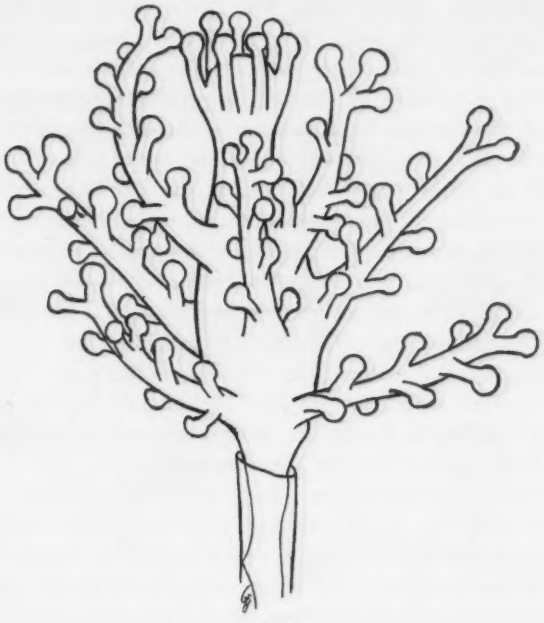


FIG. 2.

not since been a subject of record. In general aspects and size it resembles *Bougainvillia*, and was in the present instance thought to be that hydroid. A closer scrutiny soon revealed its marked differences.

Its original description from Chesapeake Bay, and its occurrence on the Fish Hawk, which had only a month previous come from Norfolk, at once suggested the probability of its having been thus transported to this locality. It is not strange, there-

[1] *Mem. Bost. Soc. Nat. Hist.*, Vol. III., 1882, p. 136.

fore, that I made the following entry in my notes at the date above mentioned: "This is a fine illustration of the importance of ships as a means in the distribution of organisms." On the following day it occurred to me to look about the docks at which the steamer was moored as to whether any signs of the hydroid might be found on the piles; and somewhat to my surprise colonies were found at several points, some of them quite remote from the ship. Immediately the query arose, Did the Fish Hawk bring the hydroid, or had it found a place on the ship from contiguous piles of the dock? The smaller and younger conditions of colonies on the ship suggested the latter alternative, but still with the prepossession of theory strongly inclining to the former. An examination of the outer side of the ship showed an almost entire absence of the hydroid, which still further emphasized the doubt as to the ship's relation to the matter of distribution. The matter found a final solution so far as the *present* issue was concerned when on August 10th Mr. Vinal Edwards having at my request brought a few hydroids from Wareham bridge at the upper arm of Buzzards Bay, and I found among the material fine colonies of the same hydroid. This of course ruled out the Fish Hawk so far as the present case was concerned, for the last habitat was entirely beyond the reach of the ship as a means of transportation.

During the current season, 1909, I looked several times at the fisheries docks for colonies during July and early August, but in vain; but again I was able to obtain luxurious colonies from the Wareham locality. This clearly established the fact that the species is thoroughly established as a permanent feature of the local fauna. But the matter as to *how* and *when* it became established must be a subject of much uncertainty for the present. That it has been established for any considerable time I seriously doubt, having been collecting throughout the region more or less assiduously for many years without previously finding any trace of its presence.

The hydroid is a large and beautiful species, the bluish color of the female gonophores making it strikingly different from almost all other species of its character. Fig. 3, copied from Clarke's paper, gives a fair idea of the main features of the hydroid.

CLYTIA VOLUBILIS. Fig. 4.

On floating masses of *Sargassum* were found prolific colonies of a hydroid which had many of the characteristics of *Clytia johnstoni*, and which I took for a time to be that species, though recognizing certain features which differed from it. During the current summer I took at Harpswell, Maine, what proved to be very typical specimens of the species, and which upon comparison with the former showed very marked and constant differences. I was therefore forced to reconsider its specific relations. In

FIG. 3.

FIG. 4.

doing this I had occasion to compare it with specimens taken at Naples several years ago, and which I had then considered as *C. johnstoni*. The two species had much in common, indeed differed hardly more than might species from remote localities. A review of the literature brought to light the fact that certain authorities have considered the two above named as identical. For example, in his monograph "Die Hydroiden des k. k. naturhistorischen Hofmuseums," Marktanner-Turneretcher has thus treated them, giving preference to the earlier name of Ellis and Solander.

A comparison of the characteristic specimens of *C. johnstoni* taken at Harpswell with the Woods Hole and Naples specimens has led me to consider both as entitled to specific distinctness, and I am therefore designating the local species as *C. volubilis*, and believe the Naples specimens to be the same. The following features are diagnostic:

Stems usually simple and unbranched, 2–4 mm. high, annulated at proximal and distal ends, occasionally indefinitely annulated throughout. Hydranths relatively large, with 20–24 stout tentacles, and with a prominent hypostome, more or less trumpet-shaped in expansion. Hydrothecæ broadly campanulate, not very deep, and with about 10–12 shallow rounded teeth, in some specimens the margins hardly more than undulate.

Gonangia borne on the reticulated hydrorhiza, rather large, and with very short plain pedicels. An interesting feature was the fact of a remarkable variation as to the aspects of these organs. Most were rather smooth, oval structures; but in not a few cases they were strongly corrugated throughout, and examples showing all phases of intergrading in this particular were easily found.

It may be well in this connection to call attention to a species of *Clytia* described by Congdon from Bermuda,[1] *C. simplex*, which has features in some measure intergrading with the one under review. I have not seen Congdon's type specimens, hence have only his general description as a guide. It will be seen that his specimens average considerably larger than my own, and the hydrotheca is given as longer, and with deeper teeth, still it might be worth an attempt to critically compare the types of these several species with a view to ascertaining just what grounds might be found bearing upon their interrelations.

Clytia cylindrica Ag.

On at least two occasions recently I have taken this beautiful little hydroid. While at times it may be found in considerable numbers, it does not seem to be especially common, though this may be due in part to its very small size. In height the simple stems are from 1–1.5 mm.; the hydrothecae about 0.5 mm.

[1] *Proc. Am. Acad. Arts and Sci.*, Vol. XLII., p. 471, 1907.

long by about 0.2 mm. broad; they are cylindrical in form, with about 8–10 sharp, deeply cut teeth. Gonangia are elongate, more or less cylindical, smooth, borne on delicate pedicels ringed at proximal and distal ends. The hydranths are extremely delicate, and with delicate orange to reddish tints just below the tentacles.

OPERCULARELLA PUMILLA Clark.

Among a few hydroids collected in March, 1908, by Dr. F. B. Sumner were found a very few specimens of this species, a record of which is important since I can find no evidence of its occurrence since that of its original description by Clark.[1] He records having taken it at Portland, Maine, and off Montauk Pt., Long Island. The related species, *O. lacerata* Hincks, he records from New Haven, Conn. Clark expressed some doubt as to whether his species really came under the genus to which it was assigned, and Nutting has expressed doubt as to the validity of the species, believing it probably identical with *O. lacerata.* My own specimens conform very closely with Clark's description and figures. It is a most beautiful and delicate little hydroid. Stems and branches are annulated throughout. No gonangia were present on my specimens.

OBELIA CONGDONI, n. sp.

On several occasions recently I have taken from floating gulf weed at Woods Hole an *Obelia* which, while apparently closely related to *O. hyalina* Clarke, differs in several important features, as will be pointed out later.

Congdon has recently described a species from Bermuda, which he referred to Clarke's *O. hyalina*,[2] but which I am convinced is identical with the species under consideration, and which seems to me to be an undescribed species.

Congdon's description and figures are sufficiently accurate to obviate necessity for any considerable details in this connection (cf. *op. cit.*). A few points which seem to be in rather sharp contrast with Clarke's species may be given.

According to Clarke[3] the "branches of the stem arise in the

[1] *Trans. Conn. Acad. Sci*, Vol. III., pp. 61–2.
[2] *Proc. Am. Acad. Arts and Sci.*, Jan., 1907.
[3] *Bull. Mus. Comp. Zoöl.*, Vol. V., 1879, p. 241.

axils of the hydrothecæ." This I do not find to be the case in the present species. Again, according to Clarke, the "gonangia are small, about twice the length of the hydrothecæ, rounded off at the distal end, with a simple spherical, terminal opening which stretches across the distal end." On the contrary, the gonangia are large, about four times the length of the hydrothecæ, and the opening is not simple, but there is a terminal neck with everted rim. It should also be said that in contrast from Clarke's species in which the colony is said to be "about 12 mm. in height, and but little branched," in the present case the colony is from 20 to 30 mm. in height, and much branched.

Gonosome. — The medusæ when liberated have 24 tentacles, but others are rapidly acquired and within ten or twelve hours many specimens have from 30 to 36. The general aspects of the medusa are distinctively obelian; there is the eversible bell, the squarish manubrium at base, with rounded oral portion, with two otocysts in each quadrant.

Regarding the species as new, and in deference to Congdon's description, I suggest as its specific designation *Obelia congdoni.*

Calycella syringa.

This species is neither new nor rare in this region. Reference is made to it for the purpose of calling attention to certain features of habitat and variation which seem of some interest and importance. Nutting refers to it as "found abundantly in the Woods Hole region, growing over all sorts of plant-like marine organisms, especially other hydroids." This statement I am able to confirm, though with a single qualification, namely, its seasonal oscillations. I have found it rather *uncommon* during the midsummer season, and have never found it actively propagating at this time by sexual modes. In early spring — March to May — it seems much more abundant and immense colonies with prolific crops of gonangia are not rare.

Another feature calls for some attention, namely, the variable size and aspects of the species in midsummer. At this time specimens found by me have been invariably of dwarfed character, so much so that for some time I was rather inclined to consider it as a distinct species. Typical specimens taken in

spring have the distinctive elongated and spirally annulated pedicels and large hydrothecæ. But specimens taken in summer, so far as my observations have gone, are uniformly and constantly small — only about one fourth that of typical specimens, and have extremely short pedicels, with only one or two annulæ, or with none. I was not unaware that Clarke [1] had referred to certain variations in size, but he made no special reference to it save as an exception. It was only after careful search among colonies of typical specimens that I was able finally to find an *occasional* specimen of this dwarfed character. I have satisfied myself that it is but another instance of that tendency to seasonal variation which is well known in other cases. It is well, however, that it

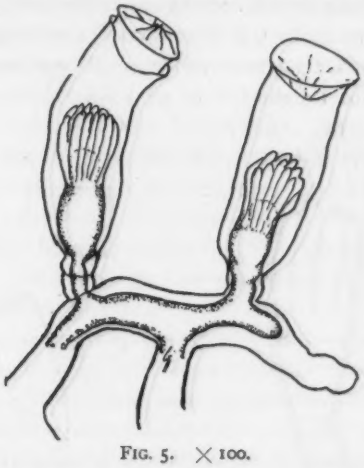


FIG. 5. × 100.

be emphasized, as well as the further fact that at certain times *dwarf features* are *distinctive* and *constant*. Fig. 5 shows some of these dwarfs enlarged.

One other feature may be referred to in connection with this phase. Clarke called particular attention to the appearance in certain hydrothecæ of this species of a "wide ring, oramented with from ten to fourteen longitudinal markings, which rises for some distance above the rim and on the summit of which there is borne either an operculum or another ring; in some cases

[1] *Trans. Conn. Acad. Sci.*, Vol. III., p. 66.

there are as many as four of these rings with an operculum at the summit." Such series of rings I have found to be rather common; but it has not been possible to distinguish, even with high powers, the "ornamental markings" to which Clarke makes reference. The surface of these secondary, or additional rings is quite as devoid of such markings as is that of the original hydrotheca itself.

CALYCELLA NUTTINGI, n. sp. (Figs. 6, 7.)

Growing upon colonies of the bryozoön, *Bugula turrita*, taken at the fishing grounds off Sankety, and later at Woods Hole, and even still later at Harpswell, Maine, I have found a microscopic species of *Calycella*, which seems to be undescribed. It is hardly more than one tenth the size of an average specimen of *C. syringa*, and differs in other respects as well. Its very minute size may probably account for the fact of its having been overlooked in

FIG. 6.

FIG. 7.

spite of continuous collecting throughout the region for many years. The following characters are diagnostic of the species:

Trophosome. — Colony composed of a creeping, filiform stolon, slightly, if at all, reticulated, from which at very irregular intervals arise the hydrothecæ. These are tubular, though not quite

cylindrical, gradually widening from base to margin, as shown in Fig. 7, and are without appreciable constriction at base where it articulates with the short, annulated pedicels, the annulations occasionally extending some distance (rarely over entire body), on the thecal walls, giving the impression of complete annulation when viewed obliquely. The hydrothecæ are very delicate, often collapsing at the distal ends when being prepared for mounting. There is a definite operculum, which often appears plaited, the individual valves being more or less difficult to distinguish. I have not determined their exact number with any degree of certainty. In many cases these valves exhibit the same aspect of inversion as is the case with *C. syringa*, but I have not found the presence of secondary rings or other marginal duplication as in the latter species. Total length of pedicel and theca 0.2–0.3 mm. or an average of about 0.25 mm., by about 0.07 mm. in diameter.

Hydranth extremely small and delicate; body elongate, cylindrical, with conical hypostome; tentacles very delicate and thread-like, usually ten in number, occasionally eight.

Gonosome unknown. The examination of many colonies from various localities failed to discover signs of gonangia. It may be probable that like *C. syringa* this species has its breeding season at some other time of year.

Habitat. — Found only associated with other hydroids, or similar organisms, *e. g.*, bryozoa, and hence is probably of commensal habit. No evidence was found indicating parasitism.

It is a pleasure to name the species, with his consent, in honor of my friend and distinguished student of hydroids, Professor C. C. Nutting.

KERATOSUM COMPLEXUM, n. gen. and sp. (Figs. 8–10.)

On three successive summers there has been taken an organism at Crab-ledge which was variously assigned to the Porifera, Bryozoa, and finally came to the writer. A glance at Fig. 8 will show how little there is from a superficial view to suggest hydroidean affinities. Indeed it was only after sections had been made, or maceration and dissection of the thing, that its true relations became evident. And it was only after considerable re-

search that its generic relations were even approximated. In 1892 Levinsen described a hydroid from Greenland (Meduser, Ctenophorer og Hydroider fra Grönlands Vestkyst),[1] which seemed to have much in common with the one here under review. He had described it as a new species under the genus *Lafœina*, Sars, naming it *L. maxima*. At first it was thought the present

FIG. 8. Photograph of colony ⅔ natural size.

species was probably identical with it, but when one undertook to work out details of morphology it became more or less certain that it not only was not the same species, but that, moreover, it could hardly belong to the same genus, if, indeed, there might not be the necessity of establishing for it a new family.

[1] "Saertryk af Vidensk. Meddel. fra den naturh. Foren.," 1892.

The genus *Lafœina* was established by Sars (Bidrag til Kundskaben om Norges Hydroider)[1] for a very minute hydroid found on stems of *Perigonimus*, the chief generic character of which was the presence of minute urticating organs, or nematophores, unlike any before known. Levinsen's description is rather inadequate, and his figures not altogether satisfactory, but to the writer there seems to be so comparatively little in common between his species and that of Sars, that it may be doubtful whether it should

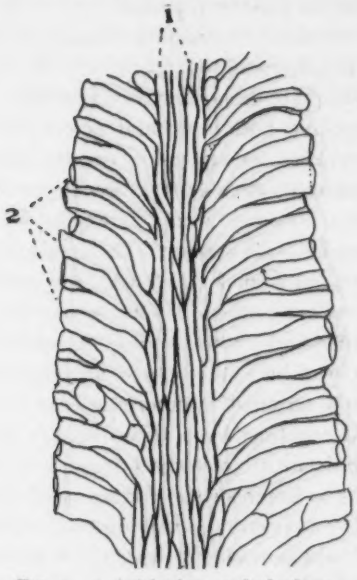


FIG. 9. 1, Axial tubes; 2, hydrothecæ.

not have been placed under a new genus. Be that as it may, it seems very sure that the present one must find different generic housing. For example, in Sars' genus the hydroid has a reticulate hydrorhiza, and Levinsen describes something of the sort for *L. maxima*, but in the present species while there may be comprised something of the sort, it would be more correct to describe the complex stem as arising from a dense, sponge-like base, etc.

Concerning the family relations I am not disposed in this connection to enter into any critical review. While the Perisi-

[1] "Saerskilt aftrykt Selsk. Forhandlinger" for 1873.

phonidæ would be the only one under which it might be placed, still the family as at present defined, according to Allman (Hydroida, Part II., p. 32),[1] would by no means provide for the species. For example, while there is an axial tubular mass, as shown in Fig. 9, there is no single one of these which bears the hydrothecæ as called for by the definition referred to. However, for the time being the species may be left under this family till such time as adequate revision may be undertaken, when the needed modifications may be provided.

As already intimated, it seems necessary to institute a new genus as well as species for our hydroid. For the genus characters the following are designated as diagnostic:

Colony sponge-like, both in general aspect and in the texture of stems and branches, as well as in growth-habit. Looked at from a short distance it resembles very much our common sponge, *Chalina arbuscula*, in almost every particular. Hence the proposed generic name — *Keratosum*. The stems arise from a disk-like spongy base and branch much after the manner of "finger sponges." These are composed of a complex and intricate mass of siphon-like tubes which ramify and anastomose irregularly, and from which arise hydrothecæ, and nematophoric organs, the latter with thecoid terminal structures similar to the former, the whole cemented together by a dense sponge-like felt of very tenacious and resistant character. Longitudinal and transverse sections of stems or branches show them to be composed of the following parts: (1) a central, axial portion, made up of more or less parallel, anastomosing tubes; (2) a peripheral portion, composed chiefly of hydrothecæ and what may be termed nematothecæ; (3) ramifying strands of cœnosarc, which seem to interpenetrate the elements of the peripheral zone. Figs. 8, 9 and 10 will show both the surface aspects as well as sectional views just mentioned.

Concerning specific diagnosis it must be regretted that the physiological state of the hydroid was such as to afford but meager characters of specific nature. The organism in all the specimens collected seemed to be in a state of hibernation, or better, perhaps, *æstivation*, no hydranths or similar organs being

[1] "Report Chall. Exped.," Vol. XXIII. (part 70), p. 32, 1888

distinguishable. Hence such organs as tentacles, gonophores, etc., which afford important specific characters, were wholly lacking. I had at first attributed this condition to bad preservation; but collections made at two subsequent seasons, in each case care being taken to preserve by approved methods, have convinced me to the contrary. It seems highly probable that this hydroid during the summer season is in a state of suspended animation, so to speak; a condition quite common among hydroids at various seasons. It must suffice in this connection to make brief reference to a few features, as hydrothecæ, etc. As shown in the figure, the hydrothecæ are tubular structures, arising from the axial tubes by rather narrow necks, and extending

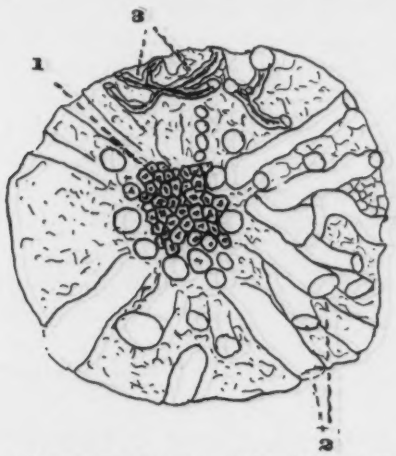


FIG. 10. Cross-section of stem. 1, Axial tubes; 2, hydrothecæ; 3, cœnosarcal strands.

upward and outward, becoming more or less curved, and opening to the surface by somewhat oblique mouths. While in many cases there seemed to be opercular-like folds at the thecal openings yet they were difficult to definitely demonstrate or describe. As to size hydrothecæ averaged about 0.7 to 1 mm. in length, by about 0.12 mm. in diameter at median portion, somewhat larger at mouth. In no case were gonangia distinguishable, nor evidences of germ cells. This might be expected as to the last, but if gonangia are an organic part of the skeleton one might

expect some trace of them in some specimens, at any rate. But none could be recognized.

Nematophores were distinguishable, and in a general way seemed similar to those described by Levinsen. They are elongated structures, cylindrical in shape, and with terminal thecoid organs which are smaller than the hydrothecae, much smaller indeed, but with no peculiar or distinguishing features. In many cases the definite organization of the nematophore was distinguishable, and the knobbed heads were found loaded with numerous nematocysts which measured about 0.015 to 0.02 mm. in length by about one third of this in diameter. In shape the nematophores may be designated as elongate-clavate; and are probably protrusible in life beyond the nematothecæ as organs of defense, or offense, according to circumstances.

In connection with the account of the morphology there should have been mentioned a matter of interest, as well as of difficulty, namely, that concerned with the attempts to dissect and separate the elements of the complex stem structure. The usual resort to boiling with potash or caustic soda, while affording some aid in clearing out the organic contents of the tubes, afforded very small aid in isolating the elements. Even when macerated for hours or days in strong solutions, or after prolonged boiling, so far as my own efforts were concerned, the macerating processes availed but little. And when resort was had to javelle water the consequences were worse, for with that agent both the cement substance and the chitinous perisarc itself were attacked about equally, and the end was, naturally, the disintegration of the entire mass.

I was interested to find a similar experience recorded by Allman (*op. cit.*, p. 47). Of the adhesion of the tubes of *Grammaria* he says: "So intimate is this adhesion that I have found no treatment, even prolonged boiling in caustic potash, of in any way overcoming it. *Grammaria* in this respect presents a striking contrast to *Cryptolaria*, as well as other genera of the Perisiphonidæ, in all of which maceration in a solution of caustic potash so weakens the adhesion of the tubes to one another that they may then be easily separated by the dissecting needle."

All in all, we have in this hydroid one of the most interesting,

and in some ways anomalous, of this remarkable group of organisms. No name compatible with the rules of nomenclature would in any measure serve to more than hint somewhat of this; hence in proposing for it the above title — *Keratosum complexum* — it may be presumed to be modestly christened!

It is a pleasure to acknowledge obligations to Dr. R. C. Osburn for aid in securing material of this species.

SYRACUSE UNIVERSITY,
September 15, 1909.

AN ECOLOGICAL STUDY OF THE PLANKTON OF SHAWNEE CAVE.

With Notes on the Cave Environment.[1]

WILL SCOTT.

With Three Figures.

During the year beginning September 7, 1907, the speleological fellowship of the department of zoölogy of Indiana University was held by the writer with residence on the Cave Farm of the University, three miles east of Mitchell, Ind.

A preliminary examination of the cave stream revealed the presence of considerable plankton. A systematic collection of the plankton was immediately begun and after some time a quantitative method applicable to the cave was developed.

The organisms constituting the plankton were found to be epigean forms. It developed that the seasonal distribution of the cave plankton is different from that of epigean streams and lakes. Its maxima and minima seemed more closely related to stream level than to any other factor of the environment.

These facts led to an examination of the surface of the region overlying the cave, in order to determine if possible the source of the plankton, and the relation of its source to its distribution in the cave. It was found that the plankton is derived from ponds in sink-holes of a particular type, and that its source is a primary factor in determining its distribution.

After the plankton enters the cave it is modified in various ways by its new environment. The cave environment is divided into two distinct regions, the terrestrial and the aquatic. These two regions are alike in that there is an absence of light in both, and that each influences the temperature of the other. They are also both affected by the form of the cave.

Some of their differences aside from their primary ones are: (1) the temperature of the air approximates the temperature of the walls of the cave very soon after entering it, while the tem-

[1] Contribution from the Zoölogical Laboratory of Indiana University, No. 104.

perature of the water approaches this constant slowly, (2) the rate of the air current in this cave is determined by the outside temperature, while the rate of water current is determined by its level, which in turn is determined by rainfall. Since the terrestrial region affects the plankton-inhabited aquatic, both regions need to be considered.

A careful examination of the bed of the stream was made for sessile and bottom-inhabiting forms with negative results.[1]

Previous Work. — Previous studies on the microörganisms of caves have been confined for the most part to the enumeration and description of species. Claus, Schmeil and Joseph have investigated the zoöplankton of some of the European caves and have recorded the species.

In this country records of microörganisms inhabiting cave water have been made by Tellkampf ('45), Packard ('89), Banta ('07) and others. Kofoid ('99) has described a towing net collection taken in Echo River, Mammoth Cave, by Eigenmann. This catch contained twenty species. Ulrich ('02) reported twenty-one species from the water of an artesian well at San Marcos, Texas. Among these were two species of cyclops, both of which he regarded as new.

The Cave. — The cave[2] in which these studies were made is at present a rather simple tube with a few side passages. A stream of some size flows through its entire length. The openings of the cave are in Section Four (4), Township Three (3) North, Range One (1) East. These openings are five in number. The

[1] I am greatly indebted to Dr. C. H. Eigenmann, professor of zoölogy, for his helpful criticisms and the loan of literature from his private library; also to Dr. Charles Zeleny, associate professor of zoölogy, for valuable suggestions. Messrs. F. C. Greene and N. E. McIndoo assisted in surveying the cave. They are entirely responsible for section II.

[2] The upper end of this cave is not known. It has been explored to a point about two miles above the outlet. At this point a mass of fallen rock nearly closes the passage. Mr. N. E. McIndoo has crawled through this passage, but it is too small to admit the boat. A stream, which drains a valley some two miles long, flows into an underground passage about four and one half miles southeast of the outlet of Shawnee Cave. This is known locally as "Mosquito Sinks" and is indicated by Newsom ('01) in section sixteen, township three, range one north. Possibly this is the upper limit of the cave. The openings where the stream "sinks" are too small to be explored. Five hundred wooden blocks, which had been soaked in paraffine, were placed in these openings, but none has been taken within the cave, to date.

lower one is the outlet and is known as Shawnee Cave. The four other openings have been formed by the collapse of two sections of the roof and are known as, Lower Twin Cave, Upper Twin Cave, Lower Dalton Cave, and Upper Dalton Cave, respectively (see map).

Vertically the cave is located in the Mitchell limestone, and has been formed by solution along seams in the rock. These seams follow approximately cardinal directions and hence cross at right angles. The result of this is that much of the cave consists of straight passages at right angles to each other. The erosive action of the stream being much greater in the eddies at the turns than in the straight passages deep pools are formed at these points.

Obstructions. — The cave stream has been obstructed more or less completely at four points in the region that I have explored. The upper obstruction has been formed by the collapse of the roof, possibly below a sink-hole, between the Dalton caves (I–36, 37).[1] The second in a similar manner between the Twin caves (I–32, 33). A large part of the upper dam has been removed by solution and erosion, so that the stream flows over it.

At the Twin caves the obstruction is complete at ordinary stages of the stream. It occurs at a right-angled turn in the cave. A new passage is being formed cutting off the obstructed corner. The lower end of this new passage is a few feet below Lower Twin Cave, the location of its upper end is not yet positively determined. The passage is too small to be explored and insufficient to accommodate the stream in times of flood; in such times, the water flows over the obstruction between the two caves and resumes its original course.

The third obstruction is 1,400 feet below Lower Twin Cave at the so-called "Big Room" (I–15, 20). Here a number of old caves crossed the present stream at a higher level. The strata between these two cave levels fell and for a time completely dammed the stream. Deposits of gravel and clay were then formed above this point. In the side passages that are protected from erosion by the cave stream, the deposits still reach the roof. Much of the obstruction and resulting deposits have been removed by the cave stream.

[1] Numbers refer to map.

Eight hundred feet below the "Big Room" is the fourth obstruction (I–13). The roof has fallen from some cause that I was unable to determine, and has completely dammed the stream. A new channel has been formed from this point to the outlet, except for a distance of 40 feet, where it flows through an old cave. The direct result of these obstructions is the formation of pools having a maximum depth of about 10 feet.

Elevation. — The outlet of Shawnee Cave is 40 feet above the level of White River which is about two and one half miles distant. The Lower Twin Cave is 30 feet above Shawnee Cave and Upper Dalton Cave is 10 feet above Lower Twin Cave. The gradient of the stream in the lower part of the cave is 40 feet to the mile. It falls very rapidly from the outlet for about 800 feet, and then has a gradient of about 12 feet to the mile. Probably this slight gradient and the close approach of the stream to local base level prevents the stream from finding a lower level when obstructed, thus causing the effect of the obstruction to continue.

As a result of the pools at the turns and above the obstructions, the water in the cave may be divided into a *constant* which is the amount of water in the pools at all times and a *variable* which is the amount of water flowing through the cave. The ratio between the constant and the variable is much greater in the lower (ordinary) stages of water than in times of flood. At ordinary stages of water, it requires a given particle of water much longer to pass through the cave than if the cave were a straight tube.

Five hundred wooden cubes which had been soaked in paraffine were put in at Lower Twin Cave, and a trap of "hardware" netting (one half inch mesh) was set at Shawnee Cave. Fourteen days later the first blocks were caught at Shawnee Cave. In times of flood the current in very rapid. Just what the rate is could not be determined as no trap could be designed that would withstand the terrific force of the stream at Shawnee Cave. Certainly not more than a few minutes are required for water to pass from Twin Cave to Shawnee Cave in times of flood.

It is evident, then, that the plankton of the cave is subjected

to the cave environment for a much longer time during the lower stages of water than during the higher stages. This has a marked effect upon the number of species and the number of individuals constituting the plankton at the different stream levels.

Light. — This cave is like most others for the greater part of its length, in that there is an absence of light. It differs from most others, in that the stream is illuminated at the points where the roof has collapsed. The stream is fairly rapid in the sections exposed to light, so that the illumination is of short duration. The illumination is strong between Dalton caves and scarcely more than twilight at low stages of the stream between Twin caves. These short exposures to light may enable some of the zoöplanktonts to feed and cause some carbon assimilation in the phytoplanktonts. The effect is probably very slight.

Temperature. (*a*) *Air.* — The temperature of the air of the interior of the cave is between 52–56° F. throughout the year. The temperature has been recorded for the last two years on a thermograph stationed fourteen hundred feet below Lower Twin Cave. The variation exceeds the error of the instrument slightly. Where the air flows out at an opening it differs in observed cases less than one (1) degree Centigrade from the temperature of the interior. Inflowing air assumes the temperature of the air in the center of the cave gradually.

On September 7, 1908, a Centigrade thermometer carried into Lower Twin Cave showed that the interior temperature was reached 428 feet from the opening. During extreme temperatures above ground this point would be farther from the opening.

(*b*) *Water.* — The water temperature varies much more than that of the air for obvious reasons. During low water the temperature of the water approaches the temperature of the walls of the cave. During a flood, it varies toward the temperature of the water outside the cave. Floods, then, cause the temperature of the cave water to lower in winter, to rise in summer, but affect it slightly when the outer temperature is near 54° F. The variation is much less in summer than in winter, because the summer floods are not so great.

In every flood observed, the extreme water temperature occurred about twenty-four hours or more after the crest of the

flood. This may be due to the influence of the residual water in the cave (see Table I.).

TABLE I.

SHOWING THE RELATION OF FLOOD TO TEMPERATURE OF CAVE WATER.

Winter.

Date.	Water Temp.	Outer Temp.	Crest of Flood.	Rainfall.
Dec. 12	11.6°+C.	<0°C.	Crest	1.48
" 13	11.5°+C.			
" 14	8.7°+C.			
" 15	8.0°+C.			
" 16	9.4°+C.			
" 21	rises to 11.0°+C.			
	Summer.			
Aug. 13	12.5° C.	max. 32.7° C. min. 21.1° C.	Crest	2.20
" 14	12.5° C.			
" 15	12.5° C.			
" 16	12.6° C.			
" 17	12.6° C.			

Air Currents. — The air in the cave is in almost constant motion. In general it flows up during the winter and down during the summer months. However, during the spring and autumn, the current reverses several times before the constant direction of the extreme season following is assumed. The direction of the current was down on October 14, and reversed on October 21, 22, 23, 26 and 30. After December 10 the air moved upward until the unstable period of spring began, which occurred about the end of March.

The rate of the current varies in different parts of the cave, being scarcely perceptible in the large rooms and very marked where the cave is small in cross-section. Observations taken at a single point indicate that the rate of the air current varies directly with the divergence of the subterranean and surface temperatures. Rate of air currents was measured with a meter recording a minimum of 30 feet per minute.

The upward moving current of cold air weathers the rocks in the regions of the lower openings of the cave, giving them in general a funnel shape. In this enlarged region there is always an upper stratum of air moving in the direction opposite to that of the primary cave air current.

The closed passages near Shawnee entrance have the ordinary

convection of a closed room, *i. e.*, a lower and an upper current moving in opposite directions. When the air currents were too weak to be measured, their direction was observed by means of a candle flame.

These results confirm and elaborate the results of Banta ('07) and Egli ('04). Banta found by weekly observations in Mayfield's Cave that the air currents reversed about October 1 and April 1. Egli found in Höll-Loch, a cavern explored by him, that the currents were down when the outer temperature was 8.1° Centigrade, and up when 2.3° Centigrade or below, being very strong at — 8° Centigrade.

Method. — It is much more difficult to collect plankton in a cave than in ordinary waters. The lack of light, the dimensions of pools, the relatively small amount of plankton, the great and sudden variations in the cave stream, and the necessity of transporting and manipulating the apparatus unassisted, rendered many of the ordinary methods impracticable.

After various experiments the method finally adopted for all quantitative work was as follows: A net was constructed of bolting silk No. 20 (Dufour) after the pattern described by Kofoid ('97). The net was suspended in a pool with about 3 inches of its filtering surface exposed. Two hundred gallons of water were dipped and poured into it with a bucket (1 ½ gal. capacity) at the rate of 10 gals. per minute. The catch was preserved in a 4 per cent. solution of formalin. I am well aware that this method results in some error (Kofoid, '97), but it was the most practicable for this investigation.

For the examination of material, glass troughs were constructed by cementing glass strips on a slide, with marine glue. The width approximated the diameter of the field of the microscope (⅔ obj., 2 in. ocu.), the length 40 mm., and the depth about 1 mm. The material was pipetted into this trough until the surface film was parallel to the slide. The entire catch was counted in quantitative work.

When higher powers of the microscope were necessary for careful study, the material was removed from this trough to a slide on which strips of cover glass were glued for the support of the cover glass. After examination, the material was washed from the trough into a new vial with 4 per cent. formalin.

Amount of the Plankton. — The amount of plankton is small when compared with the amount taken in a lake or epigean stream. In low stages, 200 gallons contained less than 1 c.c. In times of flood the catch was increased very much (200 c.c. or 300 c.c.), but this increase was largely due to silt and vegetable débris carried in suspension.

Constituents of the Plankton. — No organisms were found that were not referable to known epigean forms. Rather marked variations from the type were observed in some of the crustacea, notably in the genus *Bosmina.* However, the recent work of Wesenberg-Lund makes it advisable to withhold judgment on this point, until the local and seasonal variations in the crustacea of the ponds of the region have been investigated.

The zoöplanktonts taken included Copepoda, Cladocera, Rotifera and Protozoa.

The phytoplanktonts belonged to the following genera: *Spirogyra, Zygnema, Volvox, Closterium, Micriasteria, Vaucheria* and *Pandorina.* In addition to these, diatoms, worms, insect larvæ and fragments of spiders occurred rarely.

The planktonts having the widest temporal distribution were *Bosmina cornuta, Cyclops bicuspidatus* and *Anura cochlearis. Cyclops prasinus* outnumbered *Cyclops bicuspidatus* in November and several species of Rotifera were quite common in May.

The loricum probably enables rotifers to withstand cave conditions as all the Rotifera except two belong to the suborder Loricata. These two were found when the current was quite rapid and disappeared when the water became low and the current reduced. There may be other factors in the organization of the Loricata besides the loricum that enables them to exist under these conditions. That the rotifer fauna of the cave is included with rare exceptions in this subclass is certainly significant.

Diatoms were very rare. This was probably due to two things — (1) these forms live on the bottom of the ponds and consequently few are carried into the cave, (2) they soon succumb in the cave.

Other algæ were never taken in large quantity, but *Volvox* and *Closterium* were present in most of the catches throughout the year. Filamentous algæ were found at Shawnee Cave only in the higher stages of the stream.

The Source of the Cave Plankton. — To understand the distribution of the cave plankton, it is necessary to understand its source. It has been assumed that the plankton (at least in part) inhabiting a cave stream has been derived from the surface through sink-holes.[1] An examination of the local sink-holes made it clear that probably only a small part of the total number contribute.

Sink-holes may be divided into two principal classes, compound sink-holes and simple sink-holes. A compound sink-hole is a large depression having secondary sinks on its slopes. These arise in most cases probably by the reduction of the divides of the compound sinks by erosion. Sinks may arise secondarily on the slope of an old one.

A simple sink-hole is one without secondary sinks. Simple sink-holes agree in having the form of an inverted cone and are of three types. The first type has an opening at the apex of the cone leading to an underground passage.

The second type has this opening closed. This closure is inaugurated by rocks and earth caving in from the sides of the opening. Sediment composed of the fine clay from the sides is then deposited over this, and forms a very impermeable layer. This results in a more or less permanent pond.

The third type of simple sink-holes is like the second, except that a new opening to a subterranean passage has been formed on its sides a short distance above its lowest point. This new opening is formed from below, but the details of the process I could not determine. The result is a pond, which at its higher levels overflows into the new opening.

Open sink-holes are the rule in land covered with timber, because the erosion in such areas occurs slowly.

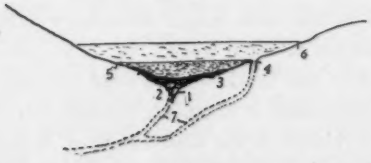
The plankton is derived from the simple sink-holes of the third type and compound sink-holes in which the lower sinks are open and the upper are closed, and in which the divides are low enough to allow the upper ones to overflow into the lower. The first type of simple sink-holes allows the water to flow so quickly into the underground channel, that organisms do not have time

[1] The cave region is a plateau which has not yet developed surface streams. The surface of this region is drained by funnel-shaped depressions called "sink-holes."

TYPE I.

TYPE II.

TYPE III.



Diagrammatic section of compound and simple sink holes. 1, original opening; 2, obstruction; 3, impervious layer of clay; 4, second opening; 5, ordinary water-level; 6, flood water-level; 7, subterranean passage.

to develop. A few wind-blown eggs and cysts may be carried into the cave and develop there, but I think it extremely doubtful. The second type of simple sinks develops many organisms, but they are not admitted to the cave stream.

Temporal Distributions. — The temporal distribution of the plankton in this cave is puzzling and the causes of this distribution are so complex that their analysis is difficult.

Although qualitative methods only were used during the fall and winter, there was less plankton in early winter than in the autumn. From this it was tentatively concluded that the main outlines of the temporal distribution of the cave plankton coincide with that of lakes and rivers in temperate latitudes, in having spring and autumnal maxima, and summer and winter minima.

After a rain of 4.71 inches which fell on February 13 and 14, I was unable to detect any organisms in the catch. Possibly a few were present and were overlooked because of the great amount of silt.

In March a series of quantitative collections was begun and continued for six months. During this period, two maxima occurred. One was on May 14, and the other was on August 13. These were maxima both in number of individuals and in number of species. Each was preceded by a very heavy rain. Between these maxima there were no rains sufficient to affect the volume of the cave stream. The maximum of May was larger than that of August (see Table II).

The February flood was accompanied by a marked decrease, but those of May and August were accompanied by a sudden increase and followed by a gradual decrease.

From these facts it is safe to conclude that excessive rainfall influences the amount of plankton per gallon of water in the cave, but not always in the same way. Excessive rainfall affects the amount of plankton in three ways. (1) The pools in plankton producing sinks of the land surface over the cave overflow and the organisms contained in them are carried into the cave. (2) The plankton is diluted in the sink where it is produced and is further diluted in the cave by the water from sink-holes of the first type. (3) The stream level is raised and the current is increased This increase in the current causes many organisms to

TABLE II.

SHOWING INFLUENCE OF FLOOD UPON TEMPORAL DISTRIBUTION.

Date.	CLASS OR GENERA.					Rainfall in Inches for Week Ending
	Cyclops.	Nauplii of *Cyclops.*	Rotifera.	*Difflugia.*	*Bosmina.*	
March 24	85	63	28	5	0	.53
" 30	75	93	74	6	0	.89
April 7	44	50	42	6	1	1.26
" 14	29	20	12	6	1	1.13
" 21	14	12	15	6	3	.32
" 28	11	46	18	3	1	.31
May 7	count incomplete on account of large amount of silt.					5.46
" 14	410	319	717	21	1998	.00
" 26	85	47	24	30	32	.85
June 2	34	30	20	16	6	.00
" 9	10	10	5	4	5	.66
" 16	11	23	14	2	6	.17
" 23	22	55	2	7	0	.00
" 30	17	42	3	10	0	.20
July 7	9	31	1	4	1	.12
" 14	28	139	3	18	0	.00
" 21	21	92	3	2	0	.15
" 30	18	84	15	5	15	.85
Aug. 7	277	325	32	34	38	1.85

be carried through the cave that would succumb to the cave environment at ordinary stream levels. The first and third of these effects of excessive rainfall are therefore positive and the second negative.

The cycle of pond life in this region is not well known, but is being investigated. It is very probable that in its main outlines it resembles that of lakes in the same latitude.

The minimum of February was due to two things, the small number of organisms produced in the pond and the great dilution by rain water.

The increase in the amount of plankton after the heavy rains of May and August was due to the fact that the amount contributed was so great that the dilution was insufficient to reduce it to the amount per gallon previously present in the cave. The increase in the number of species was caused by the rapid current carrying through many of the forms that would have succumbed to the destructive influences of the cave environment at lower stages of the water. The subsequent gradual decrease in amount and number of species was due to the destructive cave environment.

The temporal distribution of the plankton in this cave depends

upon: (1) the production of the plankton in the ponds, (2) the overflow of the ponds into the subterranean passages, (3) the dilution by rain water and interstratal seepage, (4) the rate of current in the cave stream, (5) the ability of the planktonts to live in the cave environment.

Local Distribution. — Observations taken at Dalton Cave and at Shawnee Cave indicate that the amount of plankton in the lower portion of the cave is less than in the upper portion, the amount at Shawnee varying from 40 per cent. to 80 per cent. of the amount at Upper Dalton. This is due, I think, principally to the destructive influence of the cave environment (see Table III.).

TABLE III.

Genus or Class.	Number per 200 gal. at Upper Dalton Cave.	Number per 200 gal. at Shawnee Cave.
Cyclops	59	41
Nauplii of *Cyclops*	89	64
Daphnia (immature)	0	1
Difflugia	11	3
Arcella	1	0
Œdogonium	1	0
Pandorina	2	0
Rotifera	2	4
Total	165	113

Feeding and Reproduction of the Plankton in the Cave. — The alimentary tracts of the crustacea always contained some food. In the alimentary tracts of *Cyclops* and *Bosmina* at ordinary stages of the cave stream, there was nearly as much food as in members of these genera taken above ground. In the lower stages of the stream the amount of food contained decreased.

Eggs were common in the egg sack of *Cyclops*, in the brood chambers of *Bosmina*, and upon *Anura cochlearis*. They were also observed in *Daphnia*, but the individuals of this genus were rare.

Nauplii of *Cyclops* were common throughout the year and the young of *Daphnia* and *Bosmina* were observed.

It is evident that some of the planktonts are able to continue their nutritive and reproductive processes under cave conditions, although this environment inhibits them. Whether these forms

would be able to maintain themselves in a permanent pool cut off from the cave stream is conjectural, as no such pool exists in this cave.

Tha the algæ could not live in the total darkness of the cave is certain. The method was not adapted to the investigation of the bacteria and the infusoria.

Relation of the Cave Plankton to the Permanent Cave Fauna.— The plankton of this cave does not form nor can it become a part of the permanent fauna of the cave, because the current of the stream in its higher stages is powerful enough to carry out of the cave all forms that are not strong swimmers, or have not developed the habit of living under rocks or on the bottom. *Cæcidotea*, *Crangonyx* and *Cambarus* live on the bottom and under rocks. *Amblyopsis* is a fairly strong swimmer and when struck by a current goes to the bottom or under a rock. These animals are examples of forms whose habits prevent them from being carried out of the cave.

Banta has taken *Cyclops* from the stomach of *Amblyopsis spelæus*. This suggests that the plankton is a source of food for some of the permanent cave animals.

The organisms of the cave plankton are essentially pond forms and their presence in the cave is accidental. They do not migrate into the cave to colonize it.

Summary and Conclusions. — 1. The form of the cave is determined by the direction of the seams in the limestone, the obstructions, and a factor X, which is probably elevation.

2. The form of the cave thus determined results in a large amount of residual water in the cave.

3. This residual water causes the extreme flood temperature to occur twenty-four hours or more after the crest of the flood. It also causes the rate at which the plankton is carried through the cave to vary directly as the stream level varies.

4. Water temperature varies much more than the air temperature in the interior of the cave.

5. Air currents in this cave are caused by and their rate varies directly with the divergence of terranean and subterranean temperature.

6. The amount of plankton in the cave is relatively small.

7. The plankton is composed of epigean forms and is derived from ponds in such sink-holes as have an opening above their lowest points.

8. Temporal distribution of the plankton depends upon three principal factors, the production of the plankton in the pools, excessive rainfall, and the ability of the planktons to withstand cave conditions.

9. At ordinary stages of the stream more plankton occurs in the upper part of the cave than in the lower part.

10. Some of the planktonts feed and reproduce in the cave, but these processes are more or less inhibited.

11. The plankton is not a part of the permanent cave fauna but is essentially a pond fauna accidentally carried into the cave. It is either carried through the cave or perishes in it.

LIST OF SPECIES.[1]

PROTOZOA.

Arcella vulgaris Ehrenberg.
Difflugia globosa Dujardin.
D. pyriformis Perty.
D. lobostoma Leidy.
D. acuminata Ehrenberg.
Euglena sp.

ARTHROPODA.

Cyclops bicuspidatus Claus.
C. prasinus Fischer.
C. viridus Jurine.
C. serrulatus Fischer.
C. edax Forbes.
Canthocamptus sp.
Daphnia pulex DeGeer.
Ciriodaphnia consors Birge.
Bosmina bohemica Hellick. (?)
B. cornuta Jurine.
Cydorus sphæricus Mueller.

[1] Diatoms were taken occasionally. The collections sometimes contained spiders which doubtless had fallen from the walls of the cave. One round worm and two segmented worms were observed during the year.

Pleuroxus hamatus Birge.
Cypris sp.
Campodea staphylinus (?) Westwood.
Larvæ of diptera and coleoptera rarely.

TROCHELMINTHES.

Asplanchna ebbesborni Hudson.
Triarthra longisetæ Ehrenberg.
Cathypna luna Ehrenberg.
Monastyla lunaris Ehrenberg.
M. bulla Gosse.
Branchionis militaris Ehrenberg.
B. bakeri Ehrenberg.
Noteus quadricornus Ehrenberg.
Anura cochlearis Gosse.
Notholca longispina Kellicott.

ALGÆ.

Œdogonium sp.
Cladophora sp.
Vaucheria sp.
Spirogyra sp.
Zygnema sp.
Closterium subcostatum Nord.
C. lanceolatum Kg.
Cosmarium sp.
Micrasterias sp.
Volvox globator Ehrenberg.
V. aureus Ehrenberg.
Pandorina morum Bory.
Pleurococcus sp.
Pediastrum boryanum Menegh.
Senedesmus sp.
Sphærocystis schræteri Chod.
Nostoc minutissimum Kg.
Oscillatoria sp.

LITERATURE CITED.

Banta, Arthur M.

'07 Fauna of Mayfield's Cave. Publ. of the Carnegie Institution of Washington, No. 67.

Claus, C.

'93 Neue Beobachtung über die Organization und Entwicklung von Cyclops. Ein Beitrag zur Sytematik der Cyclopiden. Arb. a. d. Zoolog. Institut Wien, Bd. 10.

Egli, Paul.

'04 Beitrag zur Kenntniss der Höhlen in der Schweiz.

Eigenmann, C. H.

The Blind Vertebrates of North America. Publ. of the Carnegie Institution of Washington, No. 104.

Joseph, G.

'79 Zur Kenntniss der in der Krainer Grotten einheimischen Räderthiere. Zool. Anz., Bd. 2, pp. 61–64.

'79b Uber Grotten-Infusorien. Ibid., pp. 114–118.

'82 Systematisches Verzeichniss der in den Tropfstein-grotten von Krain einheimischen Arthropoden nebst Diagnosen der vom Verfasser endeckten und bisher noch nicht beschriebenen Arten.

Kofoid, C. A.

'97 Plankton Studies, I. Methods and Apparatus in Use in the Biological Experiment Station of the University of Illinois. Bull. of the Illinois State Lab. of Nat. Hist.

'99 The Plankton of Echo River, Mammoth Cave. Trans. of the Am. Mic. Soc., Vol. XXI., p. 113–126.

Newsom, J. F.

'01 Geologic and Topographic Section across Southern Indiana. Twenty-sixth Annual Report of the Department of Geology and Natural Resources of Indiana.

Packard, A. S.

'88 The Cave Fauna of North America with Remarks on the Anatomy of the Brain and the origin of the Blind Species. Mem. Nat. Acad. Sci. IV., pp. 156.

Racovitza, E. G.

'07 Essai sur les Problèmes Biospeologiques. Archives de Zoologie Experimentale.

Schmeil, O.

'94 Zur Höhlenfauna des Karstes. Zeitschr. f. Naturwiss. Sachs. u. Thür., Bd. 66, pp. 339–353.

Tellkampf, T. A.

'45 Memoirs on Blind Fishes and Other Animals Living in Mammoth Cave in Kentucky. N. Y. Jour. Med. (July), pp. 84–93.

Wesenberg-Lund, C.

'08 The Plankton of the Danish Lakes.

EXPLANATION OF MAP.

Shawnee Cave (the outlet). Sec. I., No. 1.
Closed chamber caused by collapse of roof at Sec. I., Nos. 2–3.
Cascade. Sec. I., No. 6.
Double passage. Sec. I., Nos. 7–8.
Old cross cave. Sec. I., Nos. 9–10.
New passages. Sec. I., Nos. 1–8 and 11–13.
Opening in roof leading to *upper older* levels of cave. Sec. I., No. 14.
"Big Room." Sec. I., Nos. 15, 16, 17, 18, 19, 20, 21, 22.
"Fallen Rock." Sec. I., No. 31.
Lower Twin Cave. Sec. I., No. 32.
Upper Twin Cave. Sec. I., No. 33.
Roof too low for passage of boat. Sec. I., No. 34.
Deepest water in cave, 10 feet 4 inches. Sec. I., No. 35.
Lower Dalton Cave. Sec. I., No. 36.
Upper Dalton Cave. Sec. I., No. 37.

FIG. 1. Map of Shawnee Cave, section 1, from Shawnee to Lower Dalton. Length 4,453 feet. Scale 200 feet to the inch.

EXPLANATION OF MAP.

Upper Dalton Cave. Sec. II., No. 37.
"Cross bedding" in limestone. Sec. II., Nos. 46–47.
"Old passages." Sec. II., Nos. 56–57.
Obstruction past which boat cannot be taken. Sec. II., No. 63.
End of exploration. Sec. II., No. 64.

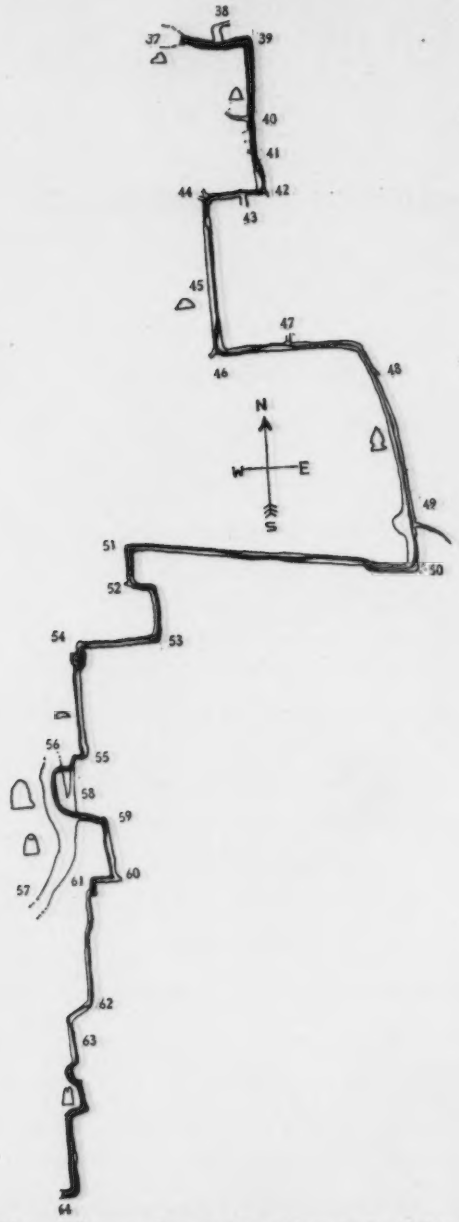


FIG. 2. Map of Shawnee Cave, section 2, from Lower Dalton to unexplored part. Length 4,674 feet. Scale 200 feet to the inch.

GENERAL LIBRARY
UNIV. OF MICH.
NOV 29 1909

BIOLOGICAL BULLETIN

OF THE

Marine Biological Laboratory

WOODS HOLE, MASS.

VOL. XVII NOVEMBER, 1909 No. 6

CONTENTS

PAGE

HARGITT, CHAS. W. *New and Little Known Hydroids of Woods Hole* 369

SCOTT, WILL. *An Ecological Study of the Plankton of Shawnee Cave* 386

PUBLISHED MONTHLY BY THE

MARINE BIOLOGICAL LABORATORY

PRINTED AND ISSUED BY

THE NEW ERA PRINTING COMPANY

LANCASTER, PA.

AGENT FOR GREAT BRITAIN

WILLIAM WESLEY & SON

28 Essex Street, Strand

London, W. C.

AGENT FOR GERMANY

R. FRIEDLÄNDER & SOHN

Berlin, N. W.

Carlstrasse, 11

Single Numbers, 75 Cents. Per Volume (6 numbers), $3.00

Entered October 10, 1902, at Lancaster, Pa., as second-class matter, under Act of Congress of July 16, 1894.

Editorial Staff.

E. G. Conklin—*Princeton University.*

Jacques Loeb—*The University of California.*

T. H. Morgan—*Columbia University.*

W. M. Wheeler—*Harvard University.*

C. O. Whitman—*The University of Chicago.*

E. B. Wilson—*Columbia University.*

Managing Editor.

Frank R. Lillie—*The University of Chicago.*

All communications and manuscripts should be sent to the Managing Editor, the University of Chicago, Sept. 15th to June 15th, or Woods Hole, Mass., June 15th to Sept. 15th. Subscriptions and other matter should be addressed to the Biological Bulletin, 41 North Queen Street, Lancaster, Pa.